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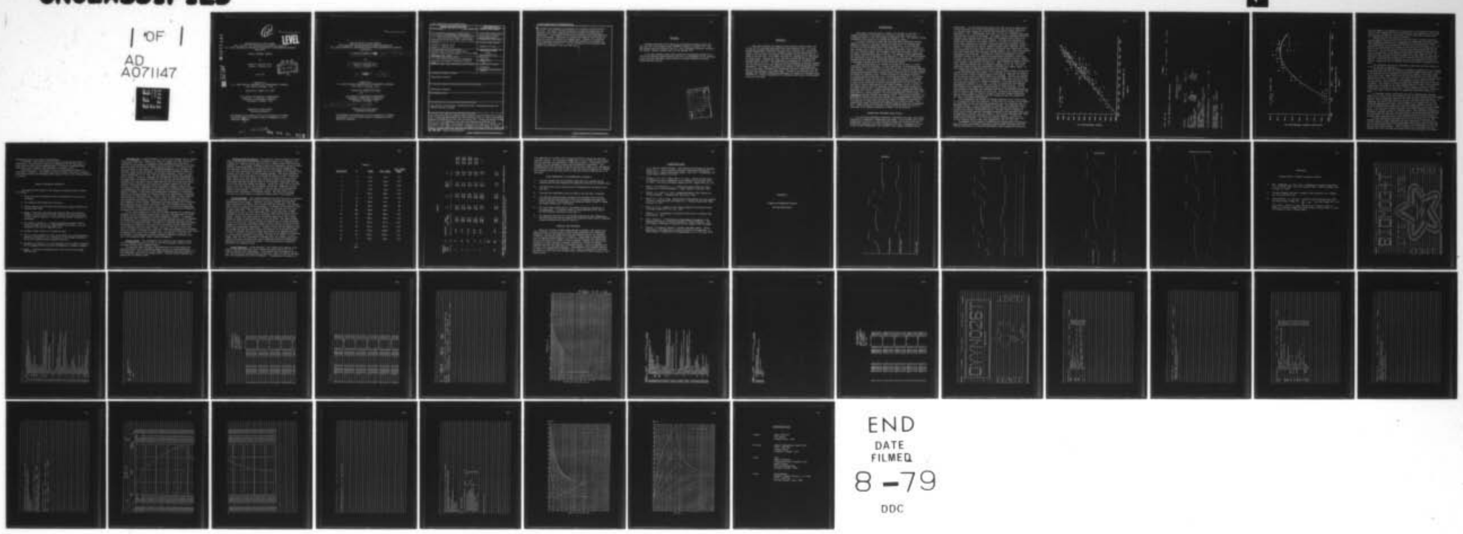

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PREDICTABILITY OF BURN DEPTH:
DATA ANALYSIS AND MATHEMATICAL MODELING BASED ON U.S. ARMY AEROMEDICAL RESEARCH LABORATORY'S EXPERIMENTAL PORCINE BURN DATA

ANNUAL SUMMARY REPORT

BY

Francis S. Knox III, Ph.D.
Ransom A. Nockton, M.S.

July 1977

Supported by
U.S. ARMY MEDICAL RESEARCH AND DEVELOPMENT COMMAND
Fort Detrick, Maryland 21701

Contract No. DAMD17-77-C-7004

LSU SCHOOL OF MEDICINE IN SHREVEPORT
Department of Physiology & Biophysics
Shreveport, Louisiana 71130

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This report describes the progress made during the period October 1976 to June 1977 in analyzing experimental burn data collected at the U.S. Army Aeromedical Research Laboratory from June 1972 to January 1973. During this period, October 1976 to June 1977, additional burn data from experiments conducted at the University of Rochester were obtained, reread and are ready to be added to the data base. Burn depths corrected for shrinkage can be 46% deeper in dermal burns. Thermal data (e.g. heat flux) recorded on FM tape during the experiments

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at USAARL was redigitized in preparation for calculation of thermal input to the skin. The effect of ambient temperature on pig skin temperature was studied to see if skin temperatures could be calculated knowing ambient temperature. The effects of anesthesia and humidity on this relationship have yet to be included. Refinement of a preliminary empirical model awaits the heat flux data now resident on the digital tapes. Sections of an analytical model employing Crank-Nicholson differencing techniques are runnable on computers using FORTRAN IV. Further development of the analytical model awaits the finalization of the burn data base.

FORWARD

Research discussed in this report was accomplished between October 1976 and June 1977 by the authors under USAMRDC Contract No. DAMD17-77-C-7004. The original data was collected at the U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama between June 1972 and January 1973.

In the data collection phase of this project the investigators adhered to the "Guide for Laboratory Animal Facilities and Care", as promulgated by the Committee on the Guide for Laboratory Animal Resources, National Academy of Sciences, National Research Council.

ABSTRACT

This report describes the progress made during the period October 1976 to June 1977 in analyzing experimental burn data collected at the U. S. Army Aeromedical Research Laboratory from June 1972 to January 1973. During this period, October 1976 to June 1977, additional burn data from experiments conducted at the University of Rochester were obtained, reread and are ready to be added to the data base. Burn depths corrected for shrinkage can be 46% deeper in dermal burns. Thermal data (e.g. heat flux) recorded on FM tape during the experiments at USAARL was redigitized in preparation for calculation of thermal input to the skin. The effect of ambient temperature on pig skin temperature was studied to see if skin temperatures could be calculated knowing ambient temperature. The effects of anesthesia and humidity on this relationship have yet to be included. Refinement of a preliminary empirical model awaits the heat flux data now resident on the digital tapes. Sections of an analytical model employing Crank-Nicholson differencing techniques are runnable on computers using FORTRAN IV. Further development of the analytical model awaits the finalization of the burn data base.

INTRODUCTION

This report covers the period 1 October 1976 through 14 June 1977. A complete description of the project can be found in the first annual report covering the period 1 July 1975 through 30 September 1976[1]. The general working hypothesis of the project can be summarized briefly as follows:

It should be possible to define the cause and effect relationships between exposure of skin to an excessive thermal environment and the resulting tissue damage by analyzing experimental exposures of pig skin to a well-controlled JP-4 fuel fire and recording furnace wall temperature, heat flux as a function of time, exposure time, skin condition, initial skin temperature, water content of the skin as a function of depth, burn damage on gross and microscopic scales, and the effects of protecting the skin by fabrics. The analysis of these experimental data should allow the development of an empirical or "black box" model describing the relationship between the thermal environment and tissue damage. The understanding that this empirical model imparts should make possible development of a reasonable analytical model for the fire-fabric-skin system.

Extensive experiments were carried out during 1972 at the U. S. Army Aeromedical Research Laboratory. In these experiments, 95 anesthetized pigs were exposed to a well-controlled JP-4 fuel fire, and the above mentioned observations recorded. The purpose of the present project is to analyze the data collected during those experiments and to develop both an empirical and an analytical model describing the response of skin, whether protected or unprotected by fabrics, to a severe thermal environment, e.g. a simulated post-crash fire. The primary accomplishments of the first year were (1) to organize the data, (2) to attempt to ascertain the validity and consistency of the experimental observations, (3) to make certain corrections for known experimental error, and (4) to extend the data base to include measurements of the depth of damage in such a way that corrections could be made for shrinkage or swelling of the tissue subsequent to the initial thermal injury. Another accomplishment was to present the data base graphically as a way of dramatizing the cause and effect relationships which might exist between or among variables. The final accomplishment was to develop a preliminary empirical (multiple discriminant) model. The technical objectives were generally met during the first year although as the accomplishments presented in more detail in the first annual report show model development was hampered by not being able to finalize the data base upon which to build the model. This second annual report summarizes the continued progress made since 30 September 1976. Before moving to a discussion of the technical objectives for Phase II, a discussion of the problems arising out of Phase I will be presented.

UNRESOLVED PROBLEMS FROM PHASE I

It is clear from experiments conducted at Rochester[2] that initial skin surface temperature is important in determining burn depth. In the USAARL study, pigs burned prior to 9/5/72 (i.e. about one half the pigs) did not have their skin temperatures measured at the time of exposure to the fire. Subsequent to 9/5/72 all skin surface temperatures were measured with a copper-constantan ribbon

thermocouple. The skin temperatures listed in the data base for the pigs burned during the summer of 1972 were extrapolated from a plot of ambient temperature vs. measured skin temperature using the data collected from September 5 to September 8, 1972. Unfortunately, only early a.m. and p.m. ambient temperatures were available to construct this graph. An analysis of this extrapolation procedure depended upon obtaining hourly temperatures and humidities from Cairns Army Airfield Weather Station, Fort Rucker, Alabama. The data were unavailable at Cairns Army Airfield but were finally found to be resident on microfiche at the United States Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, National Climatic Center, Nashville, North Carolina. Complete hourly weather reports on microfiche were obtained for Cairns Army Airfield for the period July, 1972 through January, 1973. From these records the hourly temperatures and humidities were extracted for those days on which experiments were conducted. From this list of hourly temperatures, a linear regression analysis was run between those temperatures recorded at Cairns and the early a.m. and p.m. temperatures recorded at the USAARL vivarium. Figure 1 shows a plot of the USAARL temperatures vs. the temperatures recorded at Cairns Army Airfield at approximately the same time. Table 1 shows the results of the linear regression analysis with a correlation coefficeint (R) of .90. The linear regression equation shows that temperatures at USAARL were slightly higher, on the average, than the temperatures at Cairns Army Airfield.

Considering the location of the vivarium and the terrain between Cairns Army Airfield and the USAARL burn facility, it is reasonable to expect that the temperatures at USAARL would be slightly higher on the average. Consider, for instance, the fact that the vivarium is placed between two buildings, which would attenuate any wind while Cairns Field, which is on relatively higher and more open terrain, would have quite different air mixing characteristics. The initial plan was to use this regression equation ($y = -6.9565 + 1.1435X$) to calculate the environmental temperatures at the lab at hours other than those recorded at the lab. Having thus obtained hourly temperatures, albeit calculated, at the laboratory site, we next proposed to investigate the relationship between the environmental temperature and the measured skin temperatures of the pigs. Using just the temperatures, the data, as seen in Figure 2, seems to indicate a much more complex relationship between environmental temperature and skin temperature than that proposed by Dr. Lum in the original extrapolation[1].

The investigation into possible underlying mechanisms which could account for the dispersion of the data continues. At this time it is too early to say whether the relationship between environmental temperature and skin temperature can be adequately defined. It will most probably be nonlinear. One approach would be to subject the data to multiple regression analysis including the humidity, and possibly wind velocity, as additional factors. The pigs would be expected to adopt various thermo-regulatory strategies depending on environmental factors such as temperature, humidity, and wind velocity. The fact that these pigs were under halothane anesthesia may have altered their normal response. As shown in earlier work at Rochester[1], the use of an anesthetic (chlorpromazine plus Dial in Urea-urethane) tends to allow skin temperature to fall in a cool room.

Investigation of the problem of predicting skin temperatures in anesthetized pigs when given environmental temperatures and humidities has begun and will include consideration of all possible physiological thermo-regulatory mechanisms.

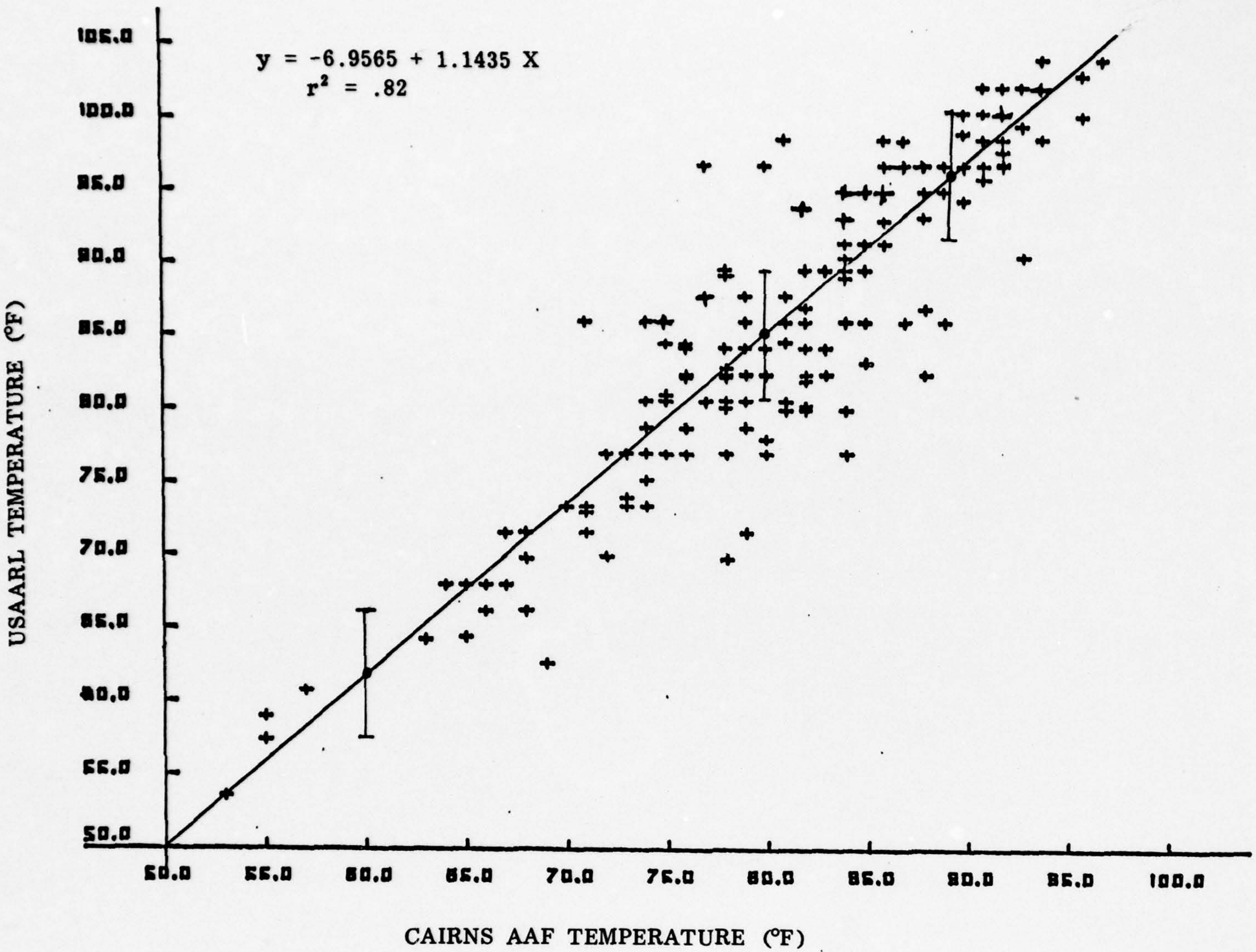
y = -6.9565 + 1.1435 X
r² = .82
USAARL TEMPERATURE (°F)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
55.0
50.0
50.0
55.0
60.0
65.0
70.0
75.0
80.0
85.0
90.0
95.0
100.0
CAIRNS AAF TEMPERATURE (°F)

Figure 1

TABLE 1

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CAIRNS AAF TEMPERATURES VS. USAARL TEMPERATURES

LINEAR REGRESSION, Y UPON X

RESULTS

STATISTIC	GROUP 1 (X)	GROUP 2 (Y)
SAMPLE SIZE	174	174
SUM	14024.	14827.
SUM OF SQUARES	0.11426E 07	0.12830E 07
MEAN	80.598	85.210
STANDARD ERROR OF MEAN	0.63849	0.80681
STANDARD DEVIATION	8.4223	10.643

SUM OF PRODUCTS = 0.12090E 07
SLOPE COEFFICIENT = 1.1435
INTERCEPT = -6.9565
COEFFICIENT OF DETERMINATION (R**2) = 0.81898
CORRELATION COEFFICIENT (R) = 0.90497

THE LINEAR REGRESSION EQUATION IS: Y = -6.9565 + 1.1435 X

STANDARD ERROR OF ESTIMATE = 4.5412
ERROR VARIANCE = 20.622
STANDARD DEVIATION OF SLOPE = 0.40993E-01
DEGREES OF FREEDOM = 172

TEST STATISTIC, T = 27.896

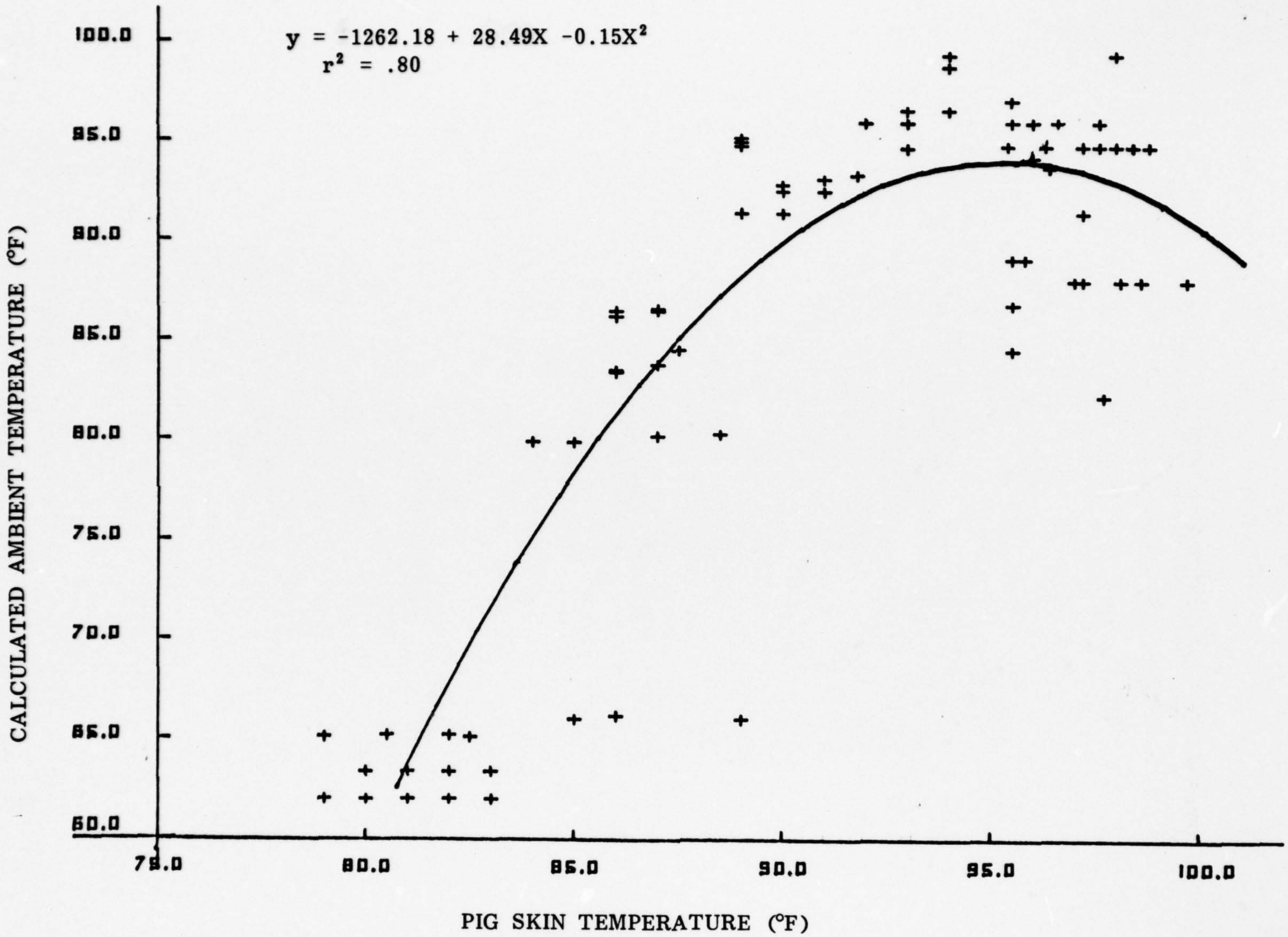
y = -1262.18 + 28.49X -0.15X²
r² = .80
CALCULATED AMBIENT TEMPERATURE (°F)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
75.0
80.0
85.0
90.0
95.0
100.0
PIG SKIN TEMPERATURE (°F)

Figure 2

This investigation will continue but it is too early to tell whether the final result will be a more adequate formula for predicting the skin temperatures of the pigs burned prior to September 5 or whether it will be impossible to predict their skin temperatures with any degree of accuracy.

Another problem which was held over from Phase I revolves around the original digitized records which were found to be inadequate for further analysis. This inadequacy necessitated our redigitizing the entire experimental record. This redigitization was accomplished at Fort Rucker during February, 1977. The process of writing programs to access the data, to strip out the pertinent data from the total record and convert that data to appropriate engineering units is under way. The new temperatures and heat fluxes resulting from this process will be incorporated into the statistical (empirical) model begun last year. In addition to data recorded during the exposure of the pigs, there are also data on these tapes concerning the response of the Aerotherm and Fabric Research Lab sensors. These data will be accessible as soon as the programs to access the data are complete and will be analyzed when the data base is reasonably free of error.

The redigitized records are considerably cleaner than previous records as shown by the plots in Appendix A.

The primary problem encountered in writing the programs to access the data automatically has been that the multi-level calibration signal employed on a number of the channels was not consistent from channel to channel or from tape to tape. There were twelve voltage levels built into the step sequence but not all twelve are present on each of the records. The reason for this is that in setting the gain and bias levels of the recordings to accommodate the output signals from the various sensors, certain subsets of the calibration voltages were used at one time or another. The program, currently being developed, will look at the calibration voltage steps and check for the ratios between the steps in order to identify which steps are present on that record. Having identified the steps, it should be a relatively simple matter to extract the appropriate calibration voltage from a table.

An additional problem encountered was that the supplemental calibration signals on the tapes (which were introduced from a battery operated four-step voltage source) were not employed consistently and often during the experimentation. For instance, these records often appear at the end of the tape rather than at the beginning, and there appear to be some changes in the voltage level over time during the experiments. Finally, the four-step battery operated calibrator was not itself calibrated sufficiently often to give one confidence in most of the voltage levels. The data on the channel connected to the HyCal Asymtotic Calorimeter appear to be unusable, since for electrical reasons, only calibration voltages from the battery operated calibrator were introduced on the HyCal Calorimeter channel. For the present, the data from the other channels will be retrieved using the automatic step calibration source and the HyCal Calorimeter data will be ignored.

In those experiments conducted prior to 9/5/72 in which heat flux was recorded using the HyCal Calorimeter and wall temperature of the furnace was recorded using a Chromel-Alumel Thermocouple, the written records of heat flux can be cross-checked using a correlation between wall temperature and the heat flux from the slug calorimeter. This correlation will be calculated from data obtained after 9/5/72 and then heat fluxes will be back-calculated for the earlier

experiments based on recorded wall temperatures.

In summary, there remains work to be done to bring the data base to a usable state. This includes 1) better skin temperatures for the early pigs; 2) better heat flux data from the digitized tapes; 3) inclusion of additional water profile data; and 4) detection and elimination of erroneous values.

What follows will be a discussion of the work proceeding in Phase II to meet Phase II objectives. The reader will notice, however, that there is considerable overlap between the development which began in Phase I and is being continued in Phase II.

PHASE II TECHNICAL OBJECTIVE

Test empirical model (Phase I) and develop an analytical model to predict burn damage.

1) Obtain raw data from Rochester study and hopefully correct them for shrinkage.

2) Test empirical model against this data base.

3) Further optimize model to obtain best performance against USAARL and Rochester data basis.

4) Result - Draft paper describing final empirical model and submit for critique to project monitors and other workers from whom constructive criticism might be expected; revise draft and consider submission for publication.

5) Re-evaluate in parallel in 1-4 above the analytical models of Stoll[3,4], Mehta and Wong[5], Morse et al (AEROTHERM)[6] and Takata[7], as to the assumptions made and the algorithms used.

6) Establish design criteria for an analytical model.

7) Review all data necessary for input to the model, e.g. skin absorptivity, diffusivity, conductivity, etc. to ascertain the underlying distributions and the 95% confidence limits associated with each.

8) Implement the model at L.S.U. and Louisiana Tech for initial development and de-bugging followed by further development on USAARL's computer.

9) Result - A preliminary analytical model which predicts burn damage from heat flux.

Rochester Data. In early November, Dr. Knox held meetings with Dr. Charles Yuile, Dr. Hinshaw, Dr. Kingsley, Dr. Bale, Dr. Adolph, and Mrs. Doris Nash, in Rochester, New York. The purpose of these meetings was to discuss the extensive set of experiments conducted at the University of Rochester in the 1950's and early 1960's on the effect of radiant energy on pig skin. Dr. Charles Yuile, now a consultant on this project and consulting pathologist at the University of Rochester, acted as host and guide. He had previously confirmed by phone that all of the biopsy slides from this project had been destroyed. However, it was further established, by Dr. Yuile, that the original tissue blocks were available and in storage. During the meetings it became apparent that the identification of the tissue blocks was going to be difficult, but that some 390-450 blocks could be identified with a pig number and an experiment and that the results of the experiments had been recorded in two University of Rochester reports, UR-338[2] and UR-553[8]. University of Rochester Report 338 entitled "Studies of Flash Burns: The Influence of Skin Temperature in the Production of Cutaneous Burns in Swine" is represented by the bulk of the biopsy material, while University of Rochester Report 553 entitled "A Theoretical and Experimental Investigation of Temperature Response of Pig Skin Exposed to Thermal Radiation" is represented by a relatively small number of biopsy specimens. However, the latter report, which constituted the major portion of Thomas P. Davis' Ph.D. thesis, includes pigs which had silver-palladium thermocouples implanted in the skin so direct measurements of skin temperature could be made. Fortunately this biopsy material was in relatively good condition and was collected towards the end of the Rochester study so that the experimental methods were well in hand. Further, the particular experiments on the influence of skin temperature in the production of burns and the temperature response of skin are important for the present study.

At Dr. Knox's request, Dr. Yuile had the biopsy specimens re-imbedded and sectioned and has subsequently graded each of the over 400 specimens in a manner consistent with the re-grading of the material collected at USAARL. In addition, he has graded some 127 specimens from the USAARL data base as a way of checking the consistency of his grading procedure against the grading procedures carried out by Drs. McCormick and Duffy. Moreover, Dr. Yuile has made some observations concerning the variability of burns and these observations will be expanded into a short technical report later this summer. All in all, some 400 or more burns from the Rochester study in which a carbon arc-clamp was employed as the radiation source are ready to be added to the data base. Any observed differences in the burns resulting from the use of a pure radiation source as opposed to a fuel fire will be important in developing the equations coupling the thermal environment to the skin in the analytical model, which is under development.

Empirical Model. The development of the empirical model started in Phase I will be expanded as soon as the data on heat flux and sensor response can be recovered from the newly redigitized tapes.

The empirical model will help in detecting errors in the data base as discussed previously[1] and in establishing design criteria for a second generation analytical model. Three sources of skin thermal properties have been obtained[3,8,9] and a MEDLARS search will be initiated shortly. Accurate thermal properties are essential for an analytical model.

Analytical Model Development. The analytical model developed at the end of Phase I and reported in the first annual progress report is now running on the Louisiana Tech computer facility and at the L.S.U. Medical Center PDP 11/40 (see Appendix B). This program calculates in-depth skin temperatures using the Crank-Nicholson differencing method but incorporates only the initial heating period. The subsequent cool-off period, damage rate and total damage calculations based on a first order chemical reaction model have now been added to the Louisiana Tech computer code under CSMP, an IBM simulation package. With some modification, this computer code should allow us to simulate the models of Stoll[3,4], Mehta and Wong[5], Morse et al[6], and Takata[7], since they are all based on the use of first order kinetics to calculate damage from calculated in-depth tissue temperature. The primary difference among the models is the selection of coefficients and exponents in the first order damage calculations. Shortly this model will be converted to run on the PDP 11/40 so that the selection of heat flux, integration interval, exposure time, skin thermal characteristics, and the like, can be entered interactively via the terminal. Subsequently, a printer "plotting" module will be added to allow visualization of the tabular results. This interactive package will allow us to more easily re-evaluate the models based on this approach.

Tissue Shrinkage. One working hypotheses has been that if skin is subjected to a high thermal input it will shrink and that this shrinkage distorted earlier measurements of burn depth. Therefore, the biopsy material was reread and depth measurement recorded to allow correction for this shrinkage. The question arises whether, in fact, there was shrinkage. An analysis was conducted in which the ratio of corrected depth to uncorrected depth was calculated for each of the 16 gross grade levels. These results, see Table 2, show that there is slight shrinkage at the low end of the scale followed by slight swelling of the tissue at moderate burn levels and fairly severe shrinkage, up to 46%, at high levels of damage. Clearly, the models based on uncorrected depth would tend to underestimate the depth of dermal damage by as much as 40-50%. The slight swelling seen in the middle level burns is evident on examination of the biopsy specimens. At this level the tissue is damaged enough to result in edema, but not so severely damaged as to have the tissue water boiled off or have the microcirculation in the upper dermal appendages compromised. Attempts to show that the regression lines for relating total flux and depth of burn were improved by correcting the depths indicate that although there is only slight improvement at the exposure times of 1, 5 and 7 seconds, the addition of depth correction did not degrade the sensitivity of the regression calculation in most cases, see Table 3 for results. It would appear, then, that while correction for shrinkage does not markedly improve the scatter of the data, corrections may still be necessary because of marked tissue shrinkage at the more severe burn levels. This correction may be especially important in the analytical model.

Sensor Experiment. In late December, 1972, sensors were exposed to the furnace, both with and without fabric between the sensor and the fire, in a study to determine their performance. At the present time there appears not to have been an FM tape recording made of these data. Thus, in order to use these data, the stripcharts will have to be digitized. A digitizing device using the A

TABLE 2

Gross Grade	N	Depth	Corr. Depth	Corr. Depth / Depth
1	5	67.5	74.2	1.10
2	5	97.5	104.5	1.07
3	4	78.1	82.4	1.06
4	1	37.5	43.3	1.15
5	7	355.4	385.9	1.09
6	21	67.9	66.6	.98
7	16	135.9	131.1	.96
8	24	147.9	144.9	.98
9	129	320.8	312.1	.97
10	146	550.9	549.5	1.00
11	30	486.3	544.9	1.12
12	74	670.6	871.3	1.30
13	56	691.3	957.4	1.38
14	41	784.2	1148.6	1.46
15	67	901.3	1180.7	1.31
16	2	537.5	754.0	1.40
	628			

TABLE 3

Exposure Time (Sec)	N	Total Flux	Depth Corr. Depth	b b	a a	SE(b) SE(b)	t t	
1	75	3.08	346.5	133.2	-63.2	23.9	5.58	(P<.001)
			379.9	161.8	-117.8	26.7	6.06	(P<.001)
3	94	7.91	585.2	76.4	-18.8	15.0	5.10	(P<.001)
			818.4	122.4	-148.9	24.1	5.07	(P<.001)
5	65	13.12	845.8	50.9	178.4	12.3	4.13	(P<.001)
			981.5	64.7	-133.0	14.7	4.40	(P<.001)
7	9	16.63	1016.7	45.9	253.6	15.9	2.89	(P<.05)
			1448.0	101.4	-238.1	21.2	4.78	(P<.01)
9	17	15.97	739.0	16.6	1004.6	19.9	-.84	---
			1008.7	12.0	1200.3	27.4	-.44	---
	260							
All	260	8.65	606.5	43.4	231.0	4.2	10.4	
			766.9	59.8	249.6	5.6	10.7	

Regression Analysis showing the effect of correcting the burn depth. e.g. at 1 second exposure the "t" statistic improved with depth correction from 5.58 to 6.06.

to D capabilities of our PDP 11/40 is being constructed to extract the data from stripchart records. The calibration voltages for this set of data have been located and the conversion from millimeters to microvolts is known. These data will be extracted from the stripchart records when the digitizer is operational. The remaining sensor data collected during the course of this study, are in the digitized records which can be retrieved as soon as the data recovery programs are finished but correlations with burn data should be made only when the data base is in its final state.

WORK REMAINING TO BE COMPLETED IN PHASE II

1) The data obtained from the Rochester study need to be entered into the computer data file and compared with comparable data from the USAARL study.

2) The heat fluxes must be extracted from the digitized data and added to the data base.

3) Corrected skin temperatures must be added to the data base, if possible.

4) The analytical model currently running on the Louisiana Tech University computer and the Department PDP 11/40 must be expanded and made interactive to facilitate a re-evaluation of the analytical models of Stoll[3,4], Mehta and Wong[5], Morse et al[6], and Takata[7].

5) The tissue water profile must be recalculated using data collected late in the experiments. (A literature search is being conducted at this time to provide additional information on this topic.)

6) The empirical model must be re-evaluated using the new skin temperatures and heat fluxes and both the empirical and analytical models must be optimized using the Rochester data base as a test set.

SUMMARY AND PROBLEMS

There are a number of tasks being pursued in parallel at the present time. With the addition of the data base of water profile information, skin temperature information, and heat flux information from the digitized records, the remainder of Phase II will proceed rapidly to a conclusion. The problem of extracting data from the digitized records appears to be the most difficult and was delayed some three or four months by a delay in contract funding. Progress was made during the period 1 October through 30 January, primarily in the area of obtaining pathology data from the University of Rochester studies. Since the signing of the contract, work has proceeded normally. Accomplishment of the technical objective for Phase II is expected by 30 September 1977. After a somewhat slow start then, the project is on the track and all tasks under the Phase II objective should be completed on time.

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APPENDIX A

Original and Redigitized Records

Showing Improvements

ORIGINAL

ORIGINAL CONTINUED

REDIGITIZED

APPENDIX B

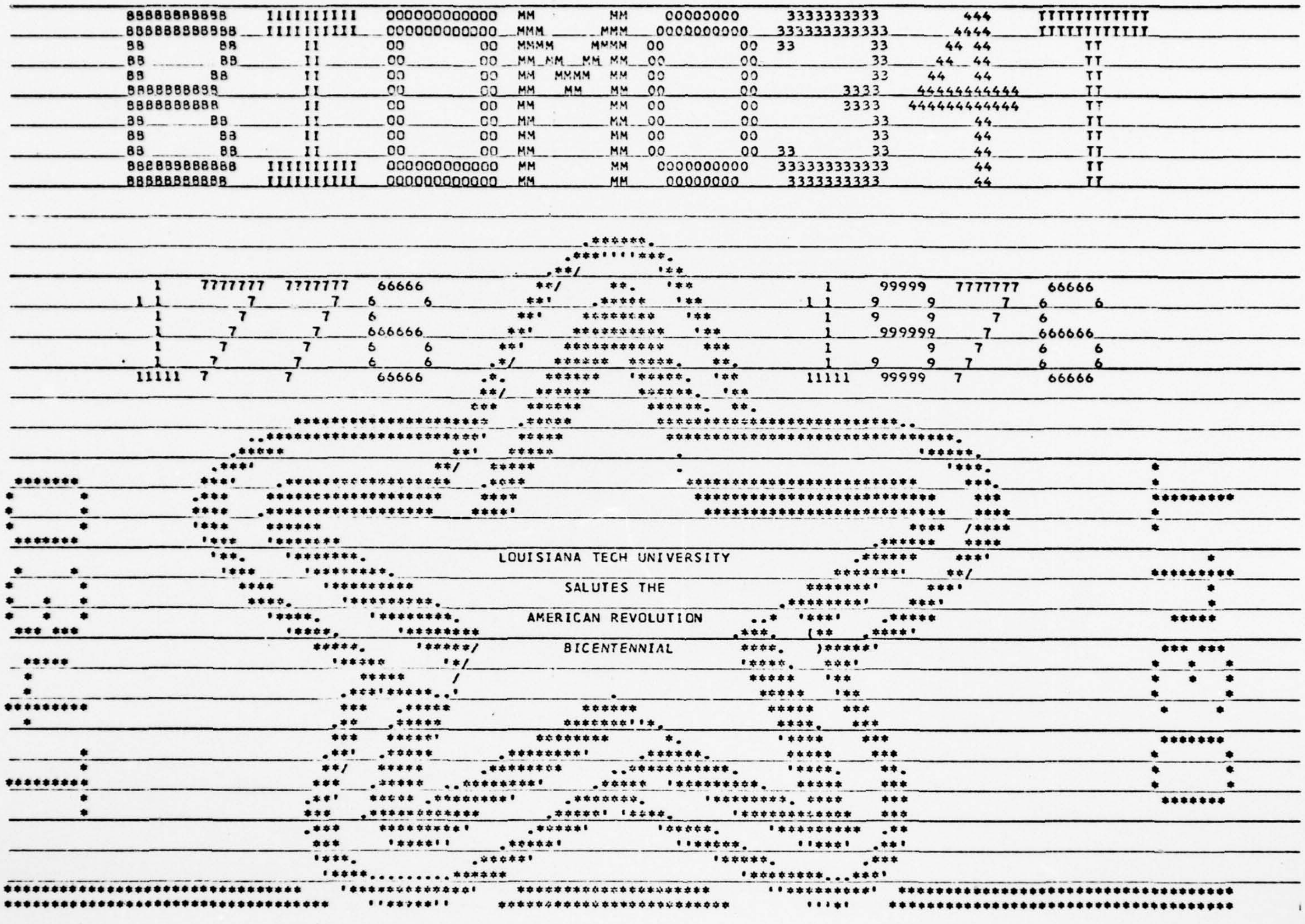
Analytical Model - Program Listings and Results.

1) JOB - BIOMO34T; La. Tech. Univ.; Calculation of In-Depth Temperatures for a 3 $CAL \cdot CM^{-2} \cdot SEC^{-1}$ Fire (150 $CAL \cdot CM^{-3} \cdot SEC^{-1}$) With No Cooling. Plot of Temp. vs. Depth.

2) The same program with minor changes in skin parameters as it compiled and run on the PDP 11/40.

3) JOB-OYYNO26T; La. Tech Univ.; Analytical Model Running Under CSMP including cooling, damage rate $\frac{dw}{dt} = DW$ and total damage (W) at the skin surface. Plots of 1) Temp, DW and W as a function of time; 2) Temp. as a function of Depth from Skin Surface at various times; 3) Temp. as a function of time at various depths.

AAAAAAAAA JOB - BIOM0347 PRINT DATE - 03/04/77 PRINT TIME - 19.52.19 AAAAAAAAA



```
$JOB            RENEAU,KP=29,TIME=30
      DIMENSIONT(250),F(250),G(250),H(250),Z(250),U(250)
      DIMENSIONSV(250),W(250),CP(250),BK(250)
      READ(5,901)TEMPIO,DENS,Q1,BL,AK
      READ(5,904)JINC,JTIME
  901 FORMAT(6F10.5)
  904 FORMAT(2I10)
      READ(5,902)(CP(J),J=1,JINC)
      READ(5,903)(BK(J),J=1,JINC)
  902 FORMAT(7F10.5)
  903 FORMAT(7F10.5)
      AJ=JINC
      H1=BL/(AJ-1.0)
      DO6J=1,JINC
    6 T(J)=TEMPIO
      WRITE(6,910)
  910 FORMAT(1H1,55X,'SKIN DIFFUSION DATA'/,55X,'INPUT PARAMETER LIST'/)
      WRITE(6,911)TEMPIO,DENS,Q1,BL,AK,JINC,JTIME
  911 FORMAT(1X,53X,8H TEMPIO=,E16.8/54X,5HDENS=,E16.8/54X,3HQ1=,E16.8/
     154X,3HBL=,E16.8/54X,3HAK=,E16.8/54X,5HJINC=,I6/54X,6HJTIME=,I6///)
      JJJJ=0
      F(1)=-BK(2)/(2.0*H1*H1)-BK(1)/(2.0*H1*H1)
      G(1)=(BK(1)+BK(2))/(2.0*H1*H1)+DENS*CP(1)/AK
      H(1)=0.0
      M=1
   11 Z(1)=-F(1)*T(2)-((BK(1)+BK(2))/(2.0*H1*H1)-(DENS*CP(1))/AK)*T(1)
     1+Q1
      N=JINC-1
      DO10J=2,N
      F(J)=-BK(J+1)/(2.0*H1*H1)
      G(J)=(BK(J)+BK(J+1))/(2.0*H1*H1)+DENS*CP(J)/AK
      H(J)=-BK(J)/(2.0*H1*H1)
   10 Z(J)=-F(J)*T(J+1)-((BK(J)+BK(J+1))/(2.*H1*H1)-DENS*CP(J)/AK)*T(J)
     1-H(J)*T(J-1)
      F(JINC)=0.0
      G(JINC)=(BK(JINC)+BK(JINC-1))/(2.0*H1*H1)+DENS*CP(JINC)/AK
      H(JINC)=-(BK(JINC)+BK(JINC-1))/(2.0*H1*H1)
      Z(JINC)=-((BK(JINC)+BK(JINC-1))/(2.*H1*H1)-(DENS*CP(JINC)/AK))*T(
     1JINC)-H(JINC)*T(JINC-1)
      W(1)=G(1)
      U(1)=Z(1)/W(1)
      DO40J=2,JINC
      JM1=J-1
      SV(JM1)=F(JM1)/W(JM1)
      W(J)=G(J)-H(J)*SV(JM1)
   40 U(J)=(Z(J)-H(J)*U(JM1))/W(J)
      T(JINC)=U(JINC)
      KK=JINC-1
      DO50J=1,KK
      KMJ=JINC-J
   50 T(KMJ)=U(KMJ)-SV(KMJ)*T(KMJ+1)
      JJJJ=JJJJ+1
      TIME=JJJJ*AK
      IF(JJJJ.EQ.M*100) GO TO 12
      GO TO 11
   12 WRITE(6,801)TIME
  801 FORMAT(1X,53X,5HTIME=,F10.6)
      WRITE(6,914)(T(J),CP(J),BK(J),J=1,JINC)
  914 FORMAT(2X,'T=',F20.5,2X,'CP=',F20.5,2X,'BK=',F20.5)
      M=M+1
```

4C.

```
      IF(M.EQ.11) GO TO 100
      GO TO 11
  100 STOP
      END
  SENTRY
```

5C

```
                         SKIN DIFFUSION DATA
                         INPUT PARAMETER LIST

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                        QI=  0.15000000E 03
                        BL=  0.19999990E 00
                        AK=  0.10000000E-01
                        JINC=     10
                        JTIME=  1000

                        TIME=  1.000000
T=      105.23230  CP=      1.00000  BK=      0.00055
T=       60.49109  CP=      1.00000  BK=      0.00065
T=       41.97743  CP=      1.00000  BK=      0.00075
T=       35.51010  CP=      1.00000  BK=      0.00090
T=       33.44914  CP=      1.00000  BK=      0.00110
T=       32.79047  CP=      1.00000  BK=      0.00125
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T=       32.50542  CP=      1.00000  BK=      0.00140
T=       32.50212  CP=      0.50000  BK=      0.00040
                        TIME=  2.000000
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T=       35.30952  CP=      1.00000  BK=      0.00125
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T=       33.09074  CP=      1.00000  BK=      0.00138
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T=       32.72934  CP=      0.50000  BK=      0.00040
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T=       56.51752  CP=      1.00000  BK=      0.00090
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T=       35.05223  CP=      1.00000  BK=      0.00138
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T=       90.45967  CP=      1.00000  BK=      0.00075
T=       68.01793  CP=      1.00000  BK=      0.00090
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T=       46.60541  CP=      1.00000  BK=      0.00125
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                        TIME=  5.000000
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T=       47.47980  CP=      1.00000  BK=      0.00135
T=       43.50800  CP=      1.00000  BK=      0.00138
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T=       59.88737  CP=      0.50000  BK=      0.00040
                              TIME=   9.000001
T=      249.30990  CP=      1.00000  BK=      0.00055
T=      192.20420  CP=      1.00000  BK=      0.00065
T=      149.96310  CP=      1.00000  BK=      0.00075
T=      120.52690  CP=      1.00000  BK=      0.00090
T=      100.88850  CP=      1.00000  BK=      0.00110
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T=       77.95367  CP=      1.00000  BK=      0.00135
T=       71.84140  CP=      1.00000  BK=      0.00138
T=       68.70078  CP=      1.00000  BK=      0.00140
T=       67.60971  CP=      0.50000  BK=      0.00040
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T=      260.28410  CP=      1.00000  BK=      0.00055
T=      202.98940  CP=      1.00000  BK=      0.00065
T=      160.31010  CP=      1.00000  BK=      0.00075
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```

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T=        80.17122  CP=        1.00000  BK=        0.00138
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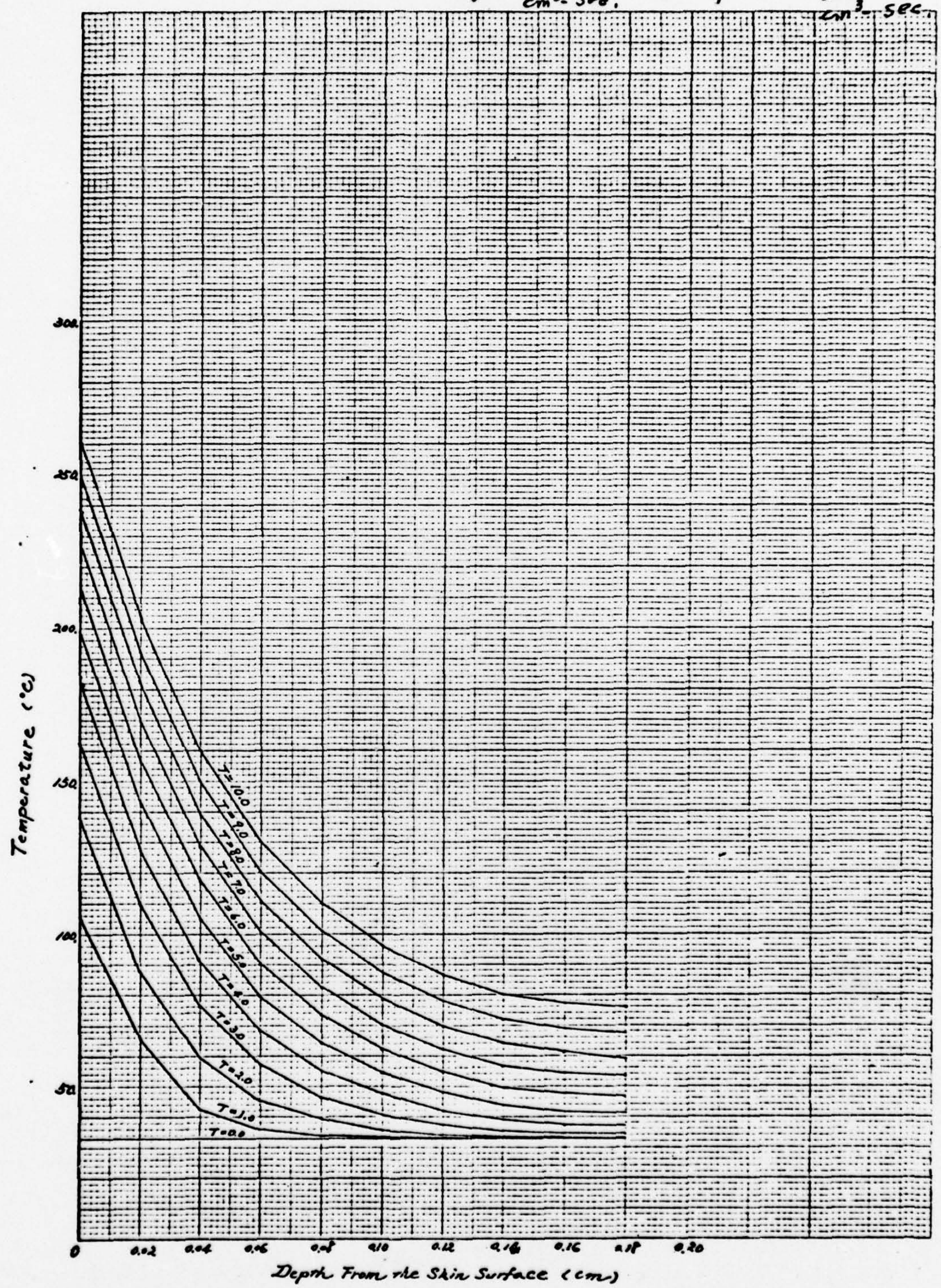
92

$q = 3.0 \frac{cal}{cm^2\text{-}sec.} \Rightarrow Q = 150 \frac{cal}{cm^3\text{-}sec.}$



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      DIMENSIONSV(250),W(250),CP(250),BK(250)
      CALL ASSIGN(1,'SKINSIM.DAT')
      READ(1,901)TEMP10,DENS,Q1,BL,AK
      READ(1,904)JINC,JTIME
  901 FORMAT(6F10.5)
  904 FORMAT(2I10)
      READ(1,902)(CP(J),J=1,JINC)
      READ(1,903)(BK(J),J=1,JINC)
  902 FORMAT(7F10.5)
  903 FORMAT(7F10.5)
      AJ=JINC
      H1=BL/(AJ-1.0)
      DO6J=1,JINC
    6 T(J)=TEMP10
      WRITE(6,910)
  910 FORMAT(1H1,55X,'SKIN DIFFUSION DATA'/,55X,'INPUT PARAMETER LIST'/)
      WRITE(6,911)TEMP10,DENS,Q1,BL,AK,JINC,JTIME
  911 FORMAT(1X,53X,8H TEMP10=,E16.8/54X,5HDENS=,E16.8/54X,3HQ1=,E16.8/
     154X,3HBL=,E16.8/54X,3HAK=,E16.8/54X,5HJINC=,I6/54X,6HJTIME=,I6///)
      JJJJ=0
      F(1)=-BK(2)/(2.0*H1*H1)-BK(1)/(2.0*H1*H1)
      G(1)=(BK(1)+BK(2))/(2.0*H1*H1)+DENS*CP(1)/AK
      H(1)=0.0
      M=1
   11 Z(1)=-F(1)*T(2)-((BK(1)+BK(2))/(2.0*H1*H1)-(DENS*CP(1))/AK)*T(1)
     1+Q1
      N=JINC-1
      DO10J=2,N
      F(J)=-BK(J+1)/(2.0*H1*H1)
      G(J)=(BK(J)+BK(J+1))/(2.0*H1*H1)+DENS*CP(J)/AK
      H(J)=-BK(J)/(2.0*H1*H1)
   10 Z(J)=-F(J)*T(J+1)-((BK(J)+BK(J+1))/(2.*H1*H1)-DENS*CP(J)/AK)*T(J)
     1-H(J)*T(J-1)
      F(JINC)=0.0
      G(JINC)=(BK(JINC)+BK(JINC-1))/(2.0*H1*H1)+DENS*CP(JINC)/AK
      H(JINC)=-(BK(JINC)+BK(JINC-1))/(2.0*H1*H1)
      Z(JINC)=-((BK(JINC)+BK(JINC-1))/(2.*H1*H1)-(DENS*CP(JINC)/AK))*T(
     1JINC)-H(JINC)*T(JINC-1)
      W(1)=G(1)
      U(1)=Z(1)/W(1)
      DO40J=2,JINC
      JM1=J-1
      SV(JM1)=F(JM1)/W(JM1)
      W(J)=G(J)-H(J)*SV(JM1)
   40 U(J)=(Z(J)-H(J)*U(JM1))/W(J)
      T(JINC)=U(JINC)
      KK=JINC-1
      DO50J=1,KK
      KMJ=JINC-J
   50 T(KMJ)=U(KMJ)-SV(KMJ)*T(KMJ+1)
      JJJJ=JJJJ+1
      TIME=JJJJ*AK
      IF(JJJJ.EQ.M*100) GO TO 12
      GO TO 11
   12 WRITE(6,801)TIME
```

```
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0054      801 FORMAT(1X,53X,5HTIME=,F10.6)
0055          WRITE(6,914)(T(J),CP(J),BK(J),J=1,JINC)
0056      914 FORMAT(2X,'T=',F20.5,2X,'CP=',F20.5,2X,'BK=',F20.5)
0057          M=M+1
0058          IF(M.EQ.11) GO TO 100
0060          GO TO 11
0061      100 STOP
0062          END
```

```
                         SKIN DIFFUSION DATA
                         INPUT PARAMETER LIST

                         TEMPI0=  0.32500000E 02
                         DENS=  0.10000000E 01
                         QI=  0.15000000E 03
                         BL=  0.20000000E 00
                         AK=  0.99999998E-02
                         JINC=    10
                         JTIME=  1000

                                         TIME=  1.000000
T=      105.23786  CP=       1.00000  BK=            0.00055
T=       60.49641  CP=       1.00000  BK=            0.00065
T=       41.98085  CP=       1.00000  BK=            0.00075
T=       35.51235  CP=       1.00000  BK=            0.00090
T=       33.45120  CP=       1.00000  BK=            0.00110
T=       32.79230  CP=       1.00000  BK=            0.00125
T=       32.58630  CP=       1.00000  BK=            0.00135
T=       32.52402  CP=       1.00000  BK=            0.00138
T=       32.50731  CP=       1.00000  BK=            0.00140
T=       32.50386  CP=       0.50000  BK=            0.00040
                                         TIME=  2.000000
T=      138.06856  CP=       1.00000  BK=            0.00055
T=       87.47366  CP=       1.00000  BK=            0.00065
T=       59.22236  CP=       1.00000  BK=            0.00075
T=       45.09154  CP=       1.00000  BK=            0.00090
T=       38.48173  CP=       1.00000  BK=            0.00110
T=       35.31398  CP=       1.00000  BK=            0.00125
T=       33.80133  CP=       1.00000  BK=            0.00135
T=       33.09455  CP=       1.00000  BK=            0.00138
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T=       56.53339  CP=       1.00000  BK=            0.00090
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T=       40.23155  CP=       1.00000  BK=            0.00125
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T=       35.05069  CP=       1.00000  BK=            0.00138
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T=       33.95599  CP=       0.50000  BK=            0.00040
                                         TIME=  4.000000
T=      181.16286  CP=       1.00000  BK=            0.00055
T=      126.72038  CP=       1.00000  BK=            0.00065
T=       90.48514  CP=       1.00000  BK=            0.00075
T=       68.84060  CP=       1.00000  BK=            0.00090
T=       54.77507  CP=       1.00000  BK=            0.00110
T=       46.62231  CP=       1.00000  BK=            0.00125
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CC        CC     YY  YY        YY  YY     NN  NN    NN  00      00            22  66                 TT
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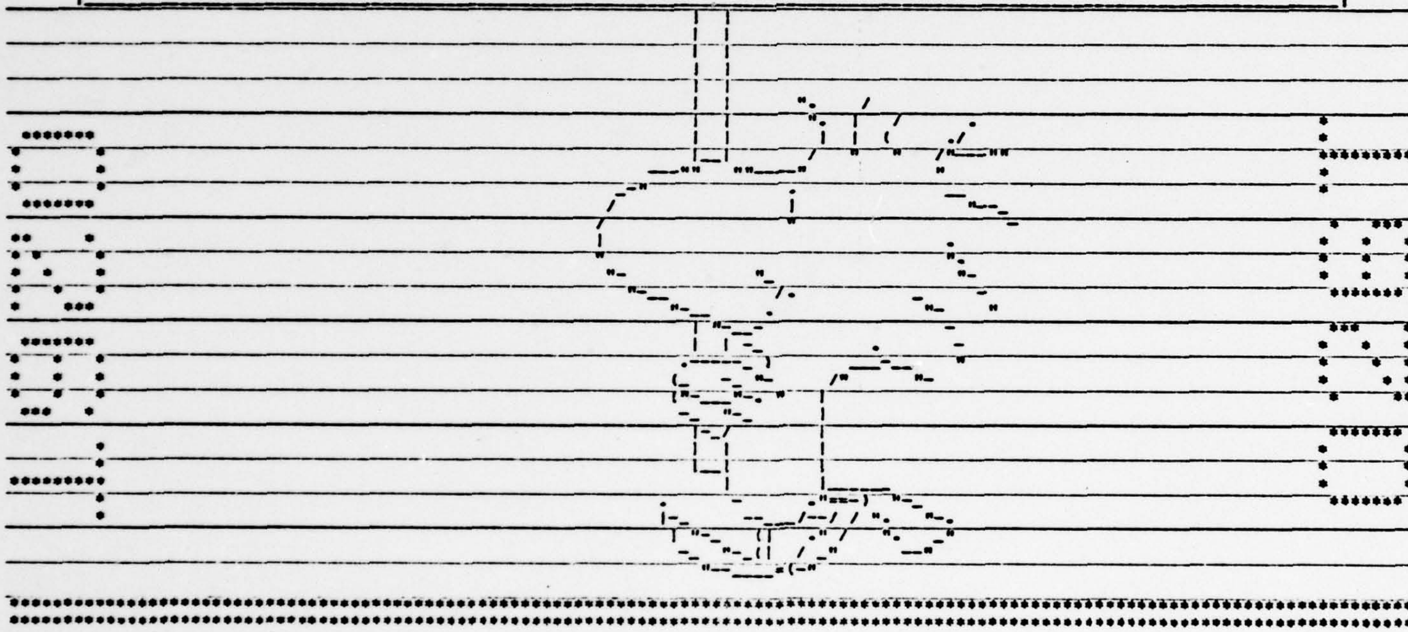
LOUISIANA TECH UNIVERSITY
COMPUTING CENTER



3Ↄ

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FORTRAN IV G LEVEL  21              BLK DATA          DATE = 77138         21/25/23             PAGE 0001

0001               BLOCK DATA                                                             CSMPDECK
0002               COMMON/ZZFDAT/F(    80)                                                CSMPDECK
                  1 /ZZHIST/KEEP,NALARM,IZ0000,IZ0001,H(     6)                           CSMPDECK
                  2 /ZZISTO/I(    30)                                                     CSMPDECK
0003               COMMON/ZZPUIN/NP(16)                                                   CSMPDECK
0004               INTEGER NP/     1,     10,     15,     18,     18,     19,     21,    21CSMPDECK
                  1,    20,    20,     6,     2,    80,     0,     1,     1/             CSMPDECK
0005               COMMON/ZZSYMB/S11( 15)                                                 CSMPDECK
0006               REAL*8 S11/                                                   'TIME  ZZ'CSMPDECK
                  1,'TIMEDELT','  ZZDELT','DELMINZZ','DELNFINT','IMZZFINT','PRDEL  ZZ'CSMPDECK
                  1,'PRDEOUTD','ELZZCUTC','DELMAXZZ','DELXW   ','  DW    ','IC     FU'CSMPDECK
                  1,'N   DWLO','G TEMP  '                                             CSMPDECK
                  1/                                                                    CSMPDECK
0007               END                                                                    CSMPDECK
```

```
FORTRAN IV G LEVEL  21                 BLK CATA          DATE = 77138          21/25/23              PAGE 0002

   *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
   *OPTIONS IN EFFECT*  NAME = BLK CATA, LINECNT =        58
   *STATISTICS*  NO DIAGNOSTICS GENERATED
```

```
FORTRAN IV G LEVEL  21                 UPDATE              DATE = 77138          21/25/23               PAGE 0001

 0001                SUBROUTINE UPDATE                                                 CSMPDECK
 0002                COMMON  TIME                                                      CSMPDECK
                    1,ZZ0000,DELT  ,ZZDELT,DELMIN,ZZDELN,FINTIM,ZZFINT,PRDEL ,ZZPRDE  CSMPDECK
                    1,OUTDEL,ZZOUTD,DELMAX,ZZDELX,W      ,DW    ,IC    ,FUN   ,DWLOG   CSMPDECK
                    1,TEMP                                                            CSMPDECK
 0003                COMMON/ZZHIST/KEEP,NALARM,IZ0000,IZ0001                           CSMPDECK
 0004                REAL    IC                                                        CSMPDECK
 0005                REAL*8  ZZTIME                                                    CSMPDECK
 0006                EQUIVALENCE(ZZTIME,TIME  )                                        CSMPDECK
 0007                GO TO(39995,39996,39997,39998),IZ0000                             CSMPDECK
            C   SYSTEM SEGMENT OF MODEL                                                CSMPDECK
 0008       39995 CONTINUE                                                             CSMPDECK
 0009                GO TO 39999                                                       CSMPDECK
            C   INITIAL SEGMENT OF MODEL                                               CSMPDECK
 0010       39996 CONTINUE                                                             CSMPDECK
 0011                GO TO 39999                                                       CSMPDECK
            C   DYNAMIC SEGMENT OF MODEL                                               CSMPDECK
 0012       39997 CONTINUE                                                             CSMPDECK
 0013                IC=0.                                                             CSMPDECK
 0014                TEMP=AFGEN(     1,FUN,TIME)                                       CSMPDECK
 0015                DWLOG=226.78474-75000./(273.+TEMP)                                CSMPDECK
 0016                DW=EXP(DWLOG)                                                     CSMPDECK
            C        W       =INTGRL     (IC        ,DW        )                       CSMPDECK
 0017                GO TO 39999                                                       CSMPDECK
            C   TERMINAL SEGMENT OF MODEL                                              CSMPDECK
 0018       39998 CONTINUE                                                             CSMPDECK
 0019       39999 CONTINUE                                                             CSMPDECK
 0020                RETURN                                                            CSMPDECK
 0021                END                                                               CSMPDECK
```

```
FORTRAN IV G LEVEL  21                UPDATE           DATE = 77138         21/25/23              PAGE 0002

      *OPTIONS IN EFFECT*  ID,EBCDIC,SOURCE,NOLIST,NODECK,LOAD,NOMAP
      *OPTIONS IN EFFECT*  NAME = UPDATE   , LINECNT =        58
      *STATISTICS*     SOURCE STATEMENTS =        21,PROGRAM SIZE =        482
      *STATISTICS*  NO DIAGNOSTICS GENERATED

      *STATISTICS*  NO DIAGNOSTICS THIS STEP 2
```

```
$$$ CONTINUOUS SYSTEM MCDELING PROGRAM III   V1M2    EXECUTION OUTPUT $$$

 FUNCTION FUN=(0.,32.50),(1.,105.24),(2.,138.07),(3.,161.86),...
 (4.,181.16),(5.,197.69),(6.,139.99),(7.,120.28),(8.,108.7C),...
 (9.,100.89),(10.,95.33)
 TIMER FINTIM=11.
 OUTPUT W,DW,TEMP
 END

TIMER VARIABLES     RKS     INTEGRATION       START TIME  = C.0
    DELT         DELMIN      FINTIM        PRDEL         OUTCEL        DELMAX
 6.87500D-03 1.1CCCCD-C6  11.000       0.0           C.11000       0.11000
**** INPLT TO FUNCTION FUN    ABCVE INPUT DATA  CURVE NO.  1   CALL     1  INPUT=  10.010      AT    10.010
$$$ SIMULATICN HALTED FCR FINISH CCNDITICN  TIME       11.000

OUTPUT VARIABLE RANGES FCR ALL RUNS IN CASE

VARIABLE      MINIMUM        MAXIMUM        VARIABLE      MINIMUM       MAXIMUM

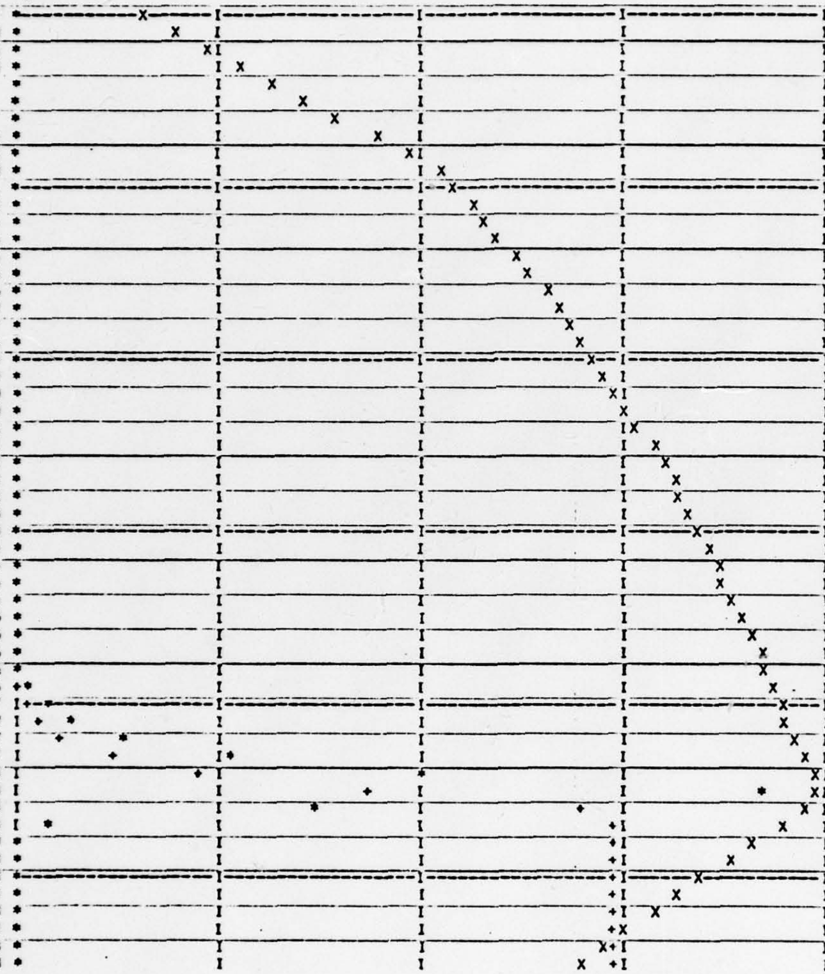
 TIME         0.0            11.0000        W              C.0           4.432482E 28
 DW           7.4545C6E-09 1.475307E 29     TEMP           32.5000        196.863
```

$\dot{q}=0$ @ $t=5.5$ sec.

At Skin surface

W ↓ $\frac{dw}{dt}$ ↓

0.0	'X'=TEMP	200.0
0.0	'*'=DW	1.60CCE 29
C.0	'+'=W	6.0000E 29



TIME	W	DW	TEMP
0.0	0.0	7.45451E-09	32.500
0.11000	7.01417E-08	3.92252E-06	40.5C1
0.22000	2.89434E-C5	1.51126E-C3	48.503
0.33000	8.60586E-03	C.436C5	56.504
0.44000	1.9902	96.164	64.506
0.5500C	358.21	16520.	72.507
0.66000	51020.	2.24820E 06	80.508
C.77000	5.84036E 06	2.46151E 08	88.51C
0.88000	5.44997E 08	2.19884E 10	96.511
0.99000	4.19997E 10	1.62381E 12	104.51
1.1000	6.91955E 11	1.31069E 13	108.52
1.2100	4.86233E 12	8.27904E 13	112.13
1.3200	3.06295E 13	5.05407E 14	115.75
1.430C	1.84594E 14	2.98430E 15	119.36
1.5400	1.C75C0E 15	1.70598E 16	122.97
1.6500	6.06334E 15	9.44967E 16	126.58
1.760C	3.31601E 16	5.07627E 17	130.19
1.8700	1.75982E 17	2.64674E 18	133.80
1.9800	9.C7098E 17	1.34C46E 19	137.41
2.0900	3.9C961E 18	4.61936E 19	140.21
2.2000	1.34132E 19	1.44765E 20	142.83
2.3100	4.29440E 19	4.47244E 20	145.44
2.420C	1.33421E 20	1.3625CE 21	148.06
2.5300	4.C6812E 20	4.09356E 21	150.68
2.6400	1.22174E 21	1.21353E 22	153.30
2.7500	3.61871E 21	3.55008E 22	155.91
2.8600	1.C5771E 22	1.02511E 23	158.53
2.9700	3.05194E 22	2.92248E 23	161.15
3.0800	8.34441E 22	7.14273E 23	163.40
3.190C	2.C6C98E 23	1.64139E 24	165.53
3.3000	4.86666E 23	3.74172E 24	167.65
3.4100	1.12338E 24	8.46252E 24	169.77
3.520C	2.557C6E 24	1.89893E 25	171.90
3.6300	5.76019E 24	4.22887E 25	174.02
3.7400	1.28629E 25	9.34643E 25	176.14
3.8500	2.84948E 25	2.C5038E 26	178.26
3.960C	6.26448E 25	4.46499E 26	180.39
4.0700	1.34723E 26	8.99877E 26	182.32
4.1800	2.74611E 26	1.73276E 27	184.14
4.2900	5.43197E 26	3.31920E 27	185.95
4.4000	1.05623E 27	6.32571E 27	187.77
4.5100	2.C3118E 27	1.19935E 28	189.59
4.6200	3.97463E 27	2.26277E 28	191.41
4.7300	7.343C9E 27	4.24797E 28	193.23
4.8400	1.38370E 28	7.93601E 28	195.05
4.9500	2.59358E 28	1.47531E 29	196.86
5.06CC	4.13366E 28	5.99645E 28	194.23
5.1700	4.40059E 28	6.57429E 27	187.88
5.2800	4.42929E 28	6.77627E 26	181.53
5.39C0	4.43218E 28	6.5486CE 25	175.19
5.5000	4.43246E 28	5.91817E 24	168.84
5.6100	4.43248E 28	4.98651E 23	162.49
5.7200	4.43248E 28	3.90502E 22	156.15
5.8300	4.43248E 28	2.83267E 21	149.80
5.9400	4.43248E 28	1.89708E 20	143.45
6.0500	4.43248E 28	2.71484E 19	139.00

6.1600	4.43248E 28	1.03632E 19	136.84
6.2700	4.43248E 28	3.91599E 18	134.67
6.3800	4.43248E 28	1.46428E 18	132.50
6.4900	4.43248E 28	5.41828E 17	130.33
6.6000	4.43248E 28	1.98326E 17	128.16
6.7100	4.43248E 28	7.18136E 16	126.00
6.8200	4.43248E 28	2.57136E 16	123.83
6.9300	4.43248E 28	9.10490E 15	121.66
7.0400	4.43248E 28	3.73294E 15	119.82
7.1500	4.43248E 28	2.00592E 15	118.54
7.2600	4.43248E 28	1.07341E 15	117.27
7.3700	4.43248E 28	5.72124E 14	116.00
7.4800	4.43248E 28	3.03649E 14	114.72
7.5900	4.43248E 28	1.60503E 14	113.45
7.7000	4.43248E 28	8.44735E 13	112.17
7.8100	4.43248E 28	4.42746E 13	110.90
7.9200	4.43248E 28	2.31029E 13	109.63
8.0300	4.43248E 28	1.27250E 13	108.47
8.1400	4.43248E 28	8.16428E 12	107.61
8.2500	4.43248E 28	5.22768E 12	106.75
8.3600	4.43248E 28	3.34056E 12	105.89
8.4700	4.43248E 28	2.13059E 12	105.03
8.5800	4.43248E 28	1.35592E 12	104.17
8.6900	4.43248E 28	8.61139E 11	103.31
8.8000	4.43248E 28	5.45772E 11	102.45
8.9100	4.43248E 28	3.45171E 11	101.59
9.0200	4.43248E 28	2.23193E 11	100.78
9.1300	4.43248E 28	1.60625E 11	100.17
9.2400	4.43248E 28	1.15486E 11	99.556
9.3500	4.43248E 28	8.29416E 10	98.944
9.4600	4.43248E 28	5.95032E 10	98.332
9.5700	4.43248E 28	4.26420E 10	97.721
9.6800	4.43248E 28	3.05246E 10	97.109
9.7900	4.43248E 28	2.18266E 10	96.498
9.9000	4.43248E 28	1.55897E 10	95.886
10.010	4.43248E 28	1.11226E 10	95.274
10.120	4.43248E 28	7.92561E 09	94.663
10.230	4.43248E 28	5.64184E 09	94.051
10.340	4.43248E 28	4.01160E 09	93.440
10.450	4.43248E 28	2.84917E 09	92.828
10.560	4.43248E 28	2.02126E 09	92.216
10.670	4.43248E 28	1.43226E 09	91.605
10.780	4.43248E 28	1.01374E 09	90.993
10.890	4.43248E 28	7.16678E 08	90.382
11.000	4.43248E 28	5.06073E 08	89.770

$$$ CONTINUOUS SYSTEM MODELING PROGRAM III V1M2 EXECUTION OUTPUT $$$

```
$$$CONTINUOUS SYSTEM MODELING PROGRAM  III   V1M2   TRANSLATOR OUTPUTS$$$

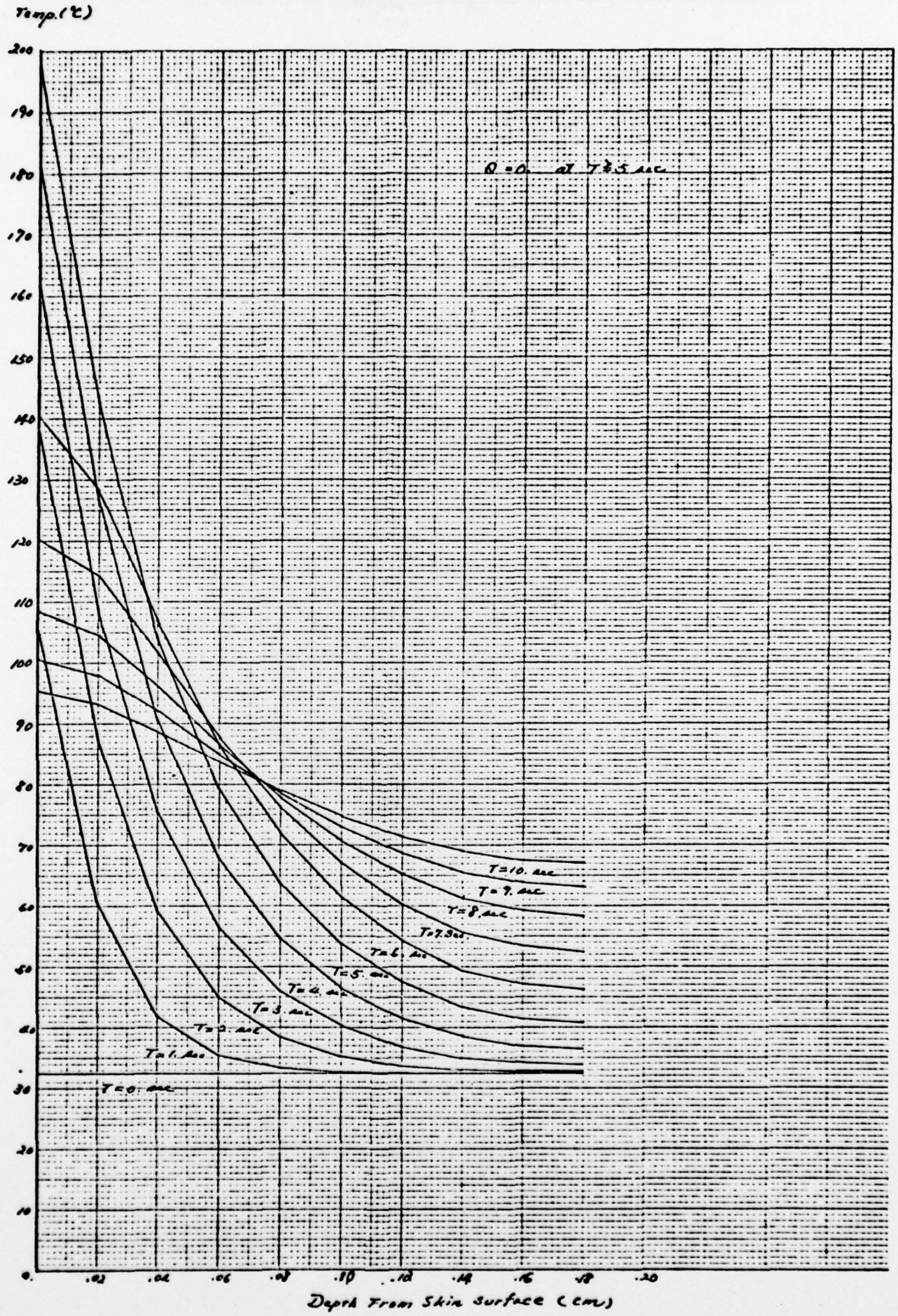
FUNCTION FUN=(0.,32.50),(1.,105.24),(2.,138.07),(3.,161.86),...
(4.,181.16),(5.,197.65),(6.,139.99),(7.,120.28),(8.,108.70),...
(9.,100.89),(10.,95.33)
IC=0.
TEMP=AFGEN(FUN,TIME)
DWLOG=226.78474-75000./(273.+TEMP)
DW=EXP(DWLOG)
W=INTGRL(IC,DW)
TIMER FINTIM=11.
OUTPUT W,DW,TEMP
END
STOP

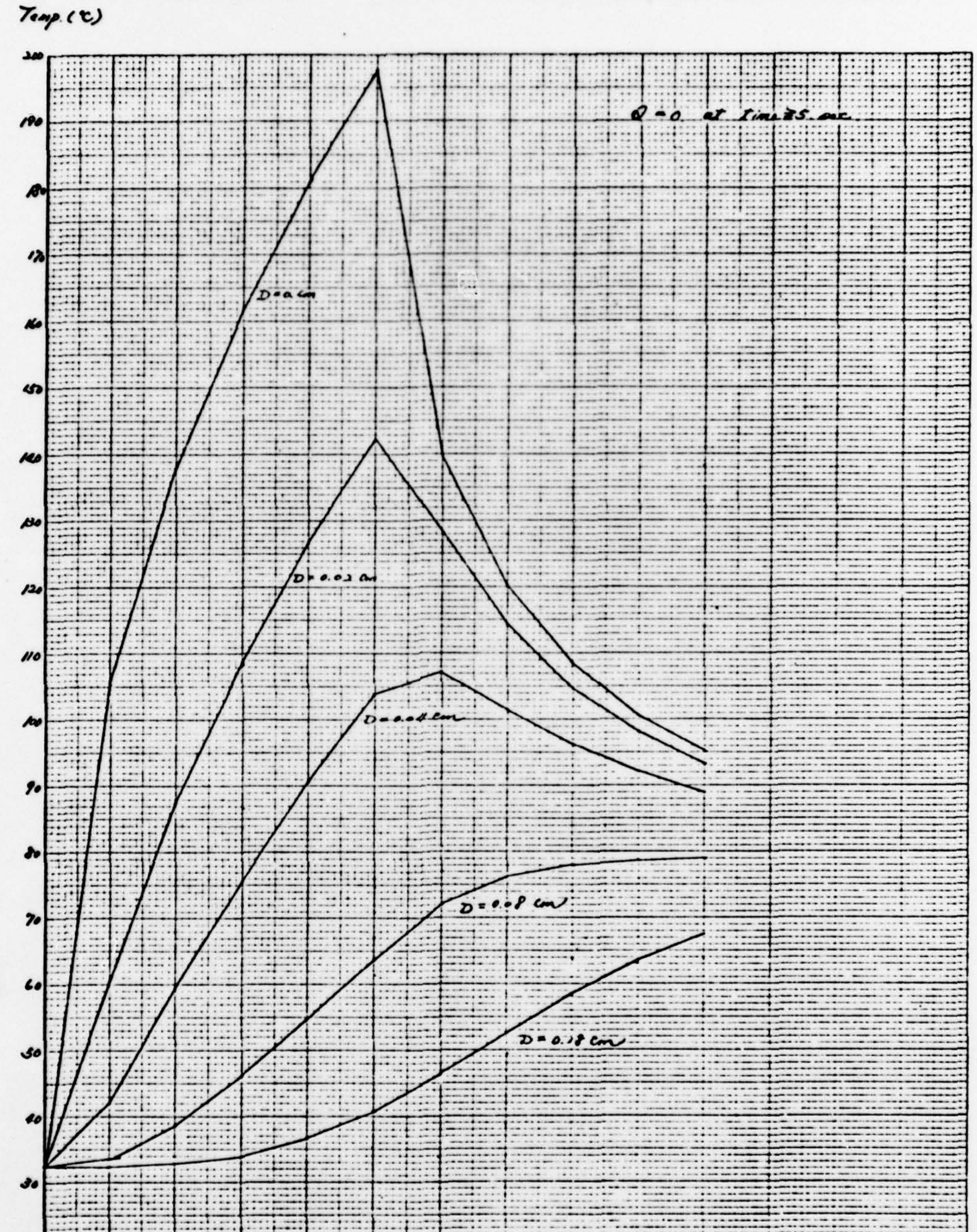
OUTPUT VARIABLE SEQUENCE
IC     TEMP   DWLOG  DW     W

$$$ TRANSLATION TABLE CONTENTS $$$        CURRENT          MAXIMUM

   MACRO AND STATEMENT OUTPUTS            11                  600
   STATEMENT INPUT WORK AREA              37                 1900
   INTEGRATORS+MEMORY BLOCK OUTPUTS        1 +  0             300
   PARAMETERS+FUNCTION GENERATORS          1 +  1             400
   STORAGE VARIABLES+INTEGRATOR ARRAYS     0 +  0/2            50
   HISTORY AND MEMORY BLOCK NAMES         21                   50
   MACRO DEFINITIONS AND NESTED MACROS     6                   50
   MACRO STATEMENT STORAGE                13                  125
   LITERAL CONSTANT STORAGE                0                  100
   SORT SECTIONS                           1                   20
   MAXIMUM STATEMENTS IN SECTION           5                  600


$$$END OF TRANSLATOR OUTPUTS$$$
```


Temp.(°C)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0.
.02
.04
.06
.08
.10
.12
.14
.16
.18
.20
Depth From Skin Surface (cm)
Q = 0. at T ≥ 5 sec
T=10. sec
T=9. sec
T=8. sec
T=7. sec
T=6. sec
T=5. sec
T=4. sec
T=3. sec
T=2. sec
T=1. sec
T=0. sec


Temp. (°C)
Q = 0 at Time ≥ 5 sec
D = 0 cm
D = 0.02 cm
D = 0.04 cm
D = 0.08 cm
D = 0.18 cm
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Time (sec)

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